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Medical Research Council
 War Memorandum No. 16

FOOD YEAST

A SURVEY OF ITS NUTRITIVE VALUE

By the
 Accessory Food Factors Committee

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FOOD YEAST

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NUTRITIVE VALUE OF YEAST

The introduction of yeast into the human dietary is not new. Yeast cells, as contained in foods and drinks fermented by naturally occurring yeasts, have formed part of the diet of man from the earliest times. The mead and beer freely taken by our own ancestors were consumed in the freshly prepared state and had undergone none of the "refinements" applied to modern beer and wine. They retained in their dregs a large number of yeast cells, which must have made a valuable addition to the daily diet by providing good protein and B vitamins synthesised during their growth. In the diets of most tropical tribes, various types of crude fermented liquors or gruels play an important part. Often, when these foods have been discarded with the advent of civilisation and its more sophisticated foods and drinks, a deterioration in health has been noted and in some instances frank deficiency diseases, hitherto unknown, have made their appearance.

Yeast has long been recommended as a popular remedy for boils, acne and similar skin infections, but only in more recent times has it been used as a therapeutic agent for the correction of certain nutritional deficiencies. Daily doses of 30 to 60 g. yeast have been found preventive and curative of endemic pellagra caused by eating an unbalanced cereal diet consisting too exclusively of maize. In Germany during the first World War a strain of yeast (*Torula*) was cultivated for human consumption, which produced little alcohol and grew well on a sugar medium containing only inorganic sources of nitrogen. This yeast was designed to provide a source of protein for the national dietary.

The growth of yeast cells in media containing sugar, molasses or hydrolysed celluloses, with inorganic sources of nitrogen, represents a profitable transaction in which these materials are converted to protein of good biological value and nutritionally valuable vitamins. In this way, valuable protective nutrients are produced from substances possessing at most energy value, which itself, in some cases, is in a form unavailable for the human subject.

The inclusion of yeast in certain tropical diets to provide additional good protein and B vitamins was recommended by the League of Nations Technical Commission on Nutrition (1938) at its meeting in Geneva in August, 1938, with the suggestion that investigations should be made of "methods by which yeast

rich in water-soluble vitamins can be produced cheaply on a large scale in such (tropical) countries". This suggestion was emphasised in the First Report of the Committee on Nutrition in the Colonial Empire (Economic Advisory Council, 1939).

The manufacture of yeast to produce a protein concentrate for feeding *livestock* was seriously considered by the Agricultural Research Council in 1939. Cultures of *Torula utilis** had already, in 1929, been brought by Professor H. Raistrick to this country from Germany, where it had been cultivated with the use of ammonia derived from atmospheric nitrogen. Work on the manufacture of *Torula utilis* on an experimental scale was started by the Department of Scientific and Industrial Research at the Chemical Research Laboratories at Teddington. In January, 1941, the Government Committee on Scientific Food Policy appointed a small sub-committee, under the chairmanship of Professor Raistrick, to consider and report on the production of yeast for *human* food, and in July of that year the Ministry of Food set up a company to arrange for the production of yeast for human consumption, now termed "Food Yeast," at the rate of 10,000 tons per annum. This company has since been superseded by the body known as Colonial Food Yeast, Ltd., it having been decided that the manufacture of dried food yeast in war time could be carried on more advantageously overseas than in this country. Under the auspices of Colonial Food Yeast, Ltd. (1944) arrangements are now in progress for the commercial production of food yeast (*Torula utilis*) in Jamaica, where waste materials from the sugar industry can be utilised economically in its manufacture, and the finished product produced at a cost which it is hoped will not exceed sixpence a pound.

The common yeast, *Saccharomyces cerevisiae*, when recovered from brewery vats, derives too bitter a taste from the brew to be generally acceptable. The type of this yeast used in bread making, which is often cultivated in a medium consisting largely of distillery waste, has a blander taste. It is not, however, cultivated as easily as *Torula* in a variety of media. The recent researches of Dr. A. C. Thaysen and his colleagues, in the Chemical Research Laboratories of the Department of Scientific and Industrial Research, on the production of food yeast, have yielded a product of delicate flavour, which can be taken alone or incorporated in many dishes without spoiling their palatability.

INVESTIGATION OF FOOD YEAST, *TORULA UTILIS*

During the last four or five years, experimental observations of various kinds have been made on behalf of the Yeast Sub-Committee of the Committee on Scientific Food Policy, the Department of Scientific and Industrial Research and the Accessory Food Factors Committee (of the Medical Research Council and the Lister Institute). These have been carried out on the dried food yeast, manufactured in the Chemical Research Laboratories of the Department of Scientific and Industrial Research at Teddington. These and other independent investigations have been directed to ascertaining the nutritive value of the yeast, and have formed part of the basis of the Government programme. It is thought advisable at this stage to present a collected account of this experimental work, as it forms the scientific justification of the belief in the nutritive value of the yeast. The results will be presented under the following headings:—

- (1) Composition and vitamin content.
- (2) Nutritive value as determined by animal experiments.
- (3) Nutritional trials on human subjects.

* This species is now known as *Torulopsis utilis*, but the older and more familiar name is used here.

(1) Composition and Vitamin Content

In Table I is given a summary of the composition and vitamin values of dried food yeast, for comparison with those of other varieties of yeast, and of a few other common foods (whole wheat flour, egg, milk, beef, liver, potato, cabbage). In Table Ia, the values are calculated from the same data on a dry weight basis.

Content of B Vitamins.—Table II gives values for the vitamin B₁ and riboflavin content of *Torula utilis* grown on various media. Estimations of the vitamin B₁ value of food yeast were carried out in the Dunn Nutritional Laboratories, Cambridge. The tests were made by the thiochrome method of Harris and Wang (1942) on samples of *Torula utilis* supplied by Dr. A. C. Thaysen, which had been grown on different media and dried by different methods. The values obtained, from 1.4 to 2.7 mg. per 100 g., showed the food yeast to be richer than other foods in this vitamin, and inferior only to some specimens of brewer's yeast. Estimations were made also by the azo method of Platt and Glock (1943).

Estimations of riboflavin were made biologically in the Division of Nutrition, Lister Institute, by a method with young rats (El Sadr, Macrae and Work, 1940; Copping, 1943 (a)). With the standard strain of *T. utilis*, neither the type of medium nor the method of drying appeared to have any effect on the riboflavin content. The special strain of *T. utilis* which grows preferably at a temperature of 36° C. appeared to be the richest in riboflavin. These values are shown in Table II, and indicate that dried food yeast is a valuable source of riboflavin, averaging at least 6 mg. per 100 g. On this basis, an amount of about 30 g. would provide the average daily human requirement of riboflavin, which is estimated to be about 2 mg. (Macrae, Barton-Wright and Copping, 1944).

Vitamin B₆ (pyridoxine) also was estimated biologically in a few samples of dried food yeast. The amounts found ranged from 4.0 to 8.0 mg. per 100 g., as compared with values of 1.2 to 2.5 mg. per 100 g. dry weight found by Waisman and Elvehjem (1941) for various types of meat muscle, which is one of the richest known sources among ordinary foods. Thus dried yeast would be a good source of pyridoxine, and superior to other sources so far examined (Copping, 1943 (b)).

The results given in Tables I and II demonstrate that food yeast is a good source of protein and a first rate source of the B group of vitamins. This is further indicated by the results of feeding experiments described in the next section.

(2) Nutritive Value as Determined by Animal Experiments

The nutritional tests on food yeast which have been made recently with animals fall chiefly into two categories, in which its nutritive value was studied as source (a) of proteins and (b) of the B group of vitamins. In some short period trials the proteins of yeast were found to possess a biological value approaching that of milk proteins (Mitchell, 1924). In growth tests of longer duration, however, yeast proteins, when providing the sole source of nitrogen in the diet, have proved inferior to casein (Still and Koch, 1928; Klose and Tevold, 1944) or to the mixed proteins of wheat in the proportions occurring naturally in the whole grain (Chick and Slack, 1945). This inferiority of yeast proteins was found by Klose and Tevold to be due to a deficiency of the essential amino-acid, methionine, a result confirmed by Himsworth and Glynn (1944). Notwithstanding this defect, when yeast is added to a diet consisting mainly of cereals, its supplementary value has been found equal to that of milk proteins (Light and Frey, 1943).

(a) *Food Yeast as a Source of Protein.*—About one-fifth of the nitrogen in yeast is non-protein in character but, in determinations of its biological value, the total

TABLE I
Nutritive Value of Dried Yeasts and of Some Other Common Foodstuffs
Composition of the Edible Portion of the Raw Foodstuff per 100 g.

Material	Water g.	Protein (N × 6.25) g.	Fat g.	Carbo- hydrate g.	Calories	Ca mg.	Fe mg.	Vitamin A I.U.	Vitamin B ₁ mg.	Riboflavin mg.	Nicotinic acid mg.	Vitamin C mg.
Yeast, dried, food, <i>Torula utilis</i> [†] brewer's, <i>Saccharo- myces cerevisiae</i> .	8	43.0	2.4	3.0	206	127	20.0	0	2.0	5.0	¶40 to 45	0
baker's, <i>Saccharo- myces cerevisiae</i> .	5	50.0	1.0	—	—	80	20.0	0	††2.0 to 10.0	4.0	¶30 to 45	0
Flour, whole wheat [‡]	5	45.0	2.0	—	—	40	25.0	0	3.0	7.0	¶30 to 40	0
Egg ..	13	§11.5	2.4	66.0	333	32	4.5	0	0.33	§§0.23	**4.4	0
Milk, whole	74	12.5	11.5	0.9	157	60	3.0	1,000	0.15	0.4	**0.06	0
	88	3.3	3.6	4.4	63	120	0.1	*70 to 140	0.045	0.15	**0.11	1.0 to 1.5
Beef [†]	59	16.0	24.0	0	276	10	4.0	50	0.08	0.25	††9.6	0
Liver, ox	70	17.0	6.0	5.0	142	10	14.0	15,000	0.40	3.0	25	0
Potato	78	2.0	0	16.2	73	8	0.7	0	0.12	0.05	**1.2	30
Cabbage	92	1.5	0	5.0	26	65	1.0	900	0.075	0.05	0.3	70

The figures unless otherwise stated are taken from the pamphlet "Nutritive Values of Wartime Foods" (Medical Research Council, 1945).
 0 = Amount present insignificant or none.
 † Average of Manitoba and English wheats.
 ‡ Average of different cuts.
 § N × 5.7.
 * According to season.
 || As carotene.
 ¶ From Appendix 1, Colonial Food Yeast, Ltd., 1944.
 ** From Tables issued by the Food and Nutrition Board of the (U.S.A.) National Research Council.
 †† On fat-free basis, Booth and Barton-Wright, 1944.
 ‡‡ Fixsen and Roscoe, 1937-38.
 §§ Bacharach, 1941.
 ||| Copping, 1943 (a).

TABLE IA

Nutritive Value of Dried Yeasts and of Some Other Common Foodstuffs, Recalculated on a Dry Matter Basis from Table I

Composition of the Edible Portion of the Raw Foodstuff per 100 g. Dry Matter

Material	Protein (N × 6.25) g.	Fat g.	Carbo- hydrate g.	Calories	Ca mg.	Fe mg.	Vitamin A I.U.	Vitamin B ₁ mg.	Riboflavin mg.	Nicotinic acid mg.	Vitamin C mg.
Yeast, dried, food, <i>Torula utilis</i> ..	47.0	2.6	3.3	224	138	22.0	0	2.2	5.4	¶43 to 49	0
brewer's, <i>Saccharomyces cerevisiae</i> .	53.0	1.0	—	—	84	21.0	0	†‡2.1 to 10.5	4.2	¶32 to 47	0
baker's, <i>Saccharomyces cerevisiae</i> .	47.0	2.1	—	—	42	26.0	0	3.2	7.4	¶32 to 42	0
Flour, whole wheat†	§13.2	2.8	76.0	383	37	5.2	0	0.38	0.26	**5.1	0
Egg ..	48.0	44.0	3.5	604	231	11.5	3,850	0.58	1.54	**0.23	0
Milk, whole	27.5	30.0	37.0	525	1,000	0.8	*580 to 1,170	0.37	1.25	**0.9	8 to 12
Beef†	39.0	58.0	0	673	24	9.8	120	0.19	0.61	†‡24	0
Liver, ox	57.0	20.0	17.0	473	33	46.0	50,000	1.33	10.0	83	0
Potato	9.1	0	74.0	332	36	3.2	0	0.54	0.23	**5.4	136
Cabbage	19.0	0	62.0	325	812	12.5	11,200	0.94	0.62	3.7	870

0 = Amount present insignificant or none.

— = Figure not available.

‡ Average of Manitoba and English wheats.

† Average of different cuts.

§ N × 5.7.

* According to season.

|| As carotene.

¶ From Appendix 1, Colonial Food Yeast, Ltd., 1944.

** From Tables issued by the Food and Nutrition Board of the (U.S.A.) National Research Council.

†† On fat-free basis, Booth and Barton-Wright, 1944.

‡‡ Fixsen and Roscoe, 1937-38.

||| Bacharach, 1941.

§§ Copping, 1943 (a).

TABLE II

Vitamin B₁ (Aneurin) and Riboflavin Content of Dried Yeast

Variety	Mode of cultivation	Method of preparation	Vitamin B ₁ mg. per 100 g.		Riboflavin mg. per 100 g.
			Thiochrome method†	Azo method†	Biological method*
<i>Torula utilis</i> ..	Molasses ..	Freeze dried	—	—	6.0
	" ..	Roller dried	1.4 to 2.3	—	6.9
	" ..	Spray dried	—	—	9.1
	" grown at 36°C.	—	—	1.2	8.2
	Pure saccharose	—	—	—	8.2
	Potato mash ..	—	2.7	—	8.3
	Straw mash ..	—	—	—	6.5
	Apple pomace	—	—	—	5.6
	Banana wort ..	—	—	—	7.6
	Bracken fronds	—	2.0	—	7.1
	" rhizomes	—	2.2	—	5.2
<i>Torula utilis</i> var. <i>major</i> .. var. <i>thermophila</i>	—	—	—	—	7.5
	Grown at 36° C.	Fresh ..	—	1.9	10.8
	" " "	After storage	—	—	9.0
<i>Saccharomyces cerevisiae</i> Distiller's .. Brewer's ..	—	—	—	—	5.3
	—	—	—	—	9.0
	—	—	—	—	—

† Harris and Wang, 1942.

† Platt and Glock, 1943.

* Copping, 1943 (a).

nitrogen has usually been included as representing "crude protein," the figure for which is obtained by multiplication of the figure for nitrogen by 6.25.

Experiments with pigs.—Macrae and his co-workers (1942), in a study of the value of food yeast as a protein supplement to a diet of maize for rearing young pigs, found the biological value of its protein to be of the same order as that of casein. When food yeast supplied about one-quarter of the nitrogen of the diet, the remaining three-quarters being derived from maize, the nutritive value of the total mixed proteins, for support of growth, was found to be about 2½ times that of the unsupplemented maize protein. In all cases an adequate supply of B vitamins was given as a protein-free yeast extract, and vitamins A and D as cod liver oil. The results of these experiments confirmed those of previous workers, who had found supplements of yeast proteins, when included in cereal diets, to exert a biological value for nutrition of growing pigs which was but little inferior to that of some proteins of animal origin, *e.g.*, fish meal (Bünger, 1939). Kon and Markuse (1931) also found yeast protein to possess a marked supplementary action for the proteins of cereals.

In an extensive series of trials with young pigs, carried out at the National Institute for Research in Dairying (Shinfield, Reading), 8 per cent. food yeast or 8 to 20 per cent. brewer's yeast was included in a mixed ration which contained weatings, barley meal, flaked maize, dried grass, ground limestone and salt. For the first 3 months these pigs thrived as well as the controls which received a diet in which 10 per cent. meat meal replaced the yeast. Later, however, some of them showed abnormal gait, with stiffness of the limbs and lameness, but this was found to be rachitic in nature, the diagnosis being confirmed by X-ray and histological examination of the bones when the animals

were slaughtered. The pigs receiving the larger proportion, 20 per cent., of yeast in the diet were the worst affected. Addition of cod liver oil to the yeast diets prevented the development of the disorder and, with diets containing 8 per cent. yeast, additional lime salts proved effective (Braude, Kon and White, 1943). It is probable that the high content of phosphorus in the yeast, when added to certain diets, may cause a Ca : P ratio which is unfavourable for correct nutrition of growing bones, though this theory has not been confirmed (Braude, Kon and White, 1944). In any case, the rachitogenic effect of yeast in the diet can easily be corrected by giving cod liver oil or additional calcium salts.

Macrae and his colleagues (1942) reared pigs satisfactorily on a maize diet containing 20 per cent. food yeast, with added CaCO_3 and cod liver oil. Worden (1943) also reared young pigs successfully on a diet of weatings and barley which contained 20 per cent. yeast and additions of CaCO_3 and cod liver oil. In practical trials under farm conditions (Macrae, 1940-41), 30 young pigs were fattened satisfactorily on a diet containing equal parts of barley and maize meal, with 10 per cent. dried yeast, supplements being given of bone ash, CaCO_3 , other minerals and cod liver oil. In these trials, and in those of Worden, brewer's yeast was used.

Experiments with other animals.—Dried yeast has been found an excellent protein feeding stuff for young dairy stock and dairy cows at levels higher than 6 per cent. of the diet ; 5 to 10 per cent. food yeast is recommended as a useful supplement to the balancer meal supplied at present for domestic poultry keepers. (See also reports of experiments with rats of Osborne and Mendel (1919), and with poultry of Plimmer *et al.* (1934).)

(b) *Food Yeast as a Source of B Vitamins. Experiments with rats.*—In the following experiments, carried out in the Division of Nutrition, Lister Institute, the content of B vitamins in food yeast was compared with that of whole wheat (Chick, 1941).

Young rats about 4 weeks old, of body weight 45 to 50 g., received diets composed largely of ground whole wheat (82 per cent. in the diet) or of white flour of 73 per cent. extraction of the grain (86 per cent. in the diet), both flours being derived from the same grist. Salt mixture was added to correct the mineral deficiencies of the flours, and also a small amount of fat (4 per cent.) as hardened arachis oil. All the diets were arranged, by the addition of casein, to contain an optimum amount (about 18 per cent.) of protein. Cod liver oil to provide vitamins A and D was given separately to each animal. To the white flour diet extra vitamin B_1 was added, also dried food yeast in the percentages of 5, $2\frac{1}{2}$ or $1\frac{1}{4}$, with proportionally less casein to make allowance for the protein added with the yeast.

The results of the experiments, which lasted 6 to 8 weeks, showed that the rats receiving the white flour diet with 5 per cent. yeast thrived better than those receiving the wholemeal diet ; those receiving the white flour diet with $2\frac{1}{2}$ per cent. yeast developed at a rate slightly greater than the latter (see Figure 1). The utilisation of the diet, as measured by the g. dry food eaten per g. weight increase, was about the same in both cases. The animals which received the white flour diet with $1\frac{1}{4}$ per cent. yeast were inferior in growth to those on the wholemeal diet. It was concluded that addition of about 2 per cent. of food yeast to a diet composed mainly of white flour would provide the extra B vitamins contained in the corresponding flour milled from the whole grain. Addition of extra vitamin B_1 to the diet of white flour and yeast made no significant difference, so that the yeast must have provided an adequate amount of this vitamin as well as of the B_2 group of vitamins. The results of some further preliminary experiments suggested that the wholemeal diet was deficient in the " filtrate factor " members of this group.

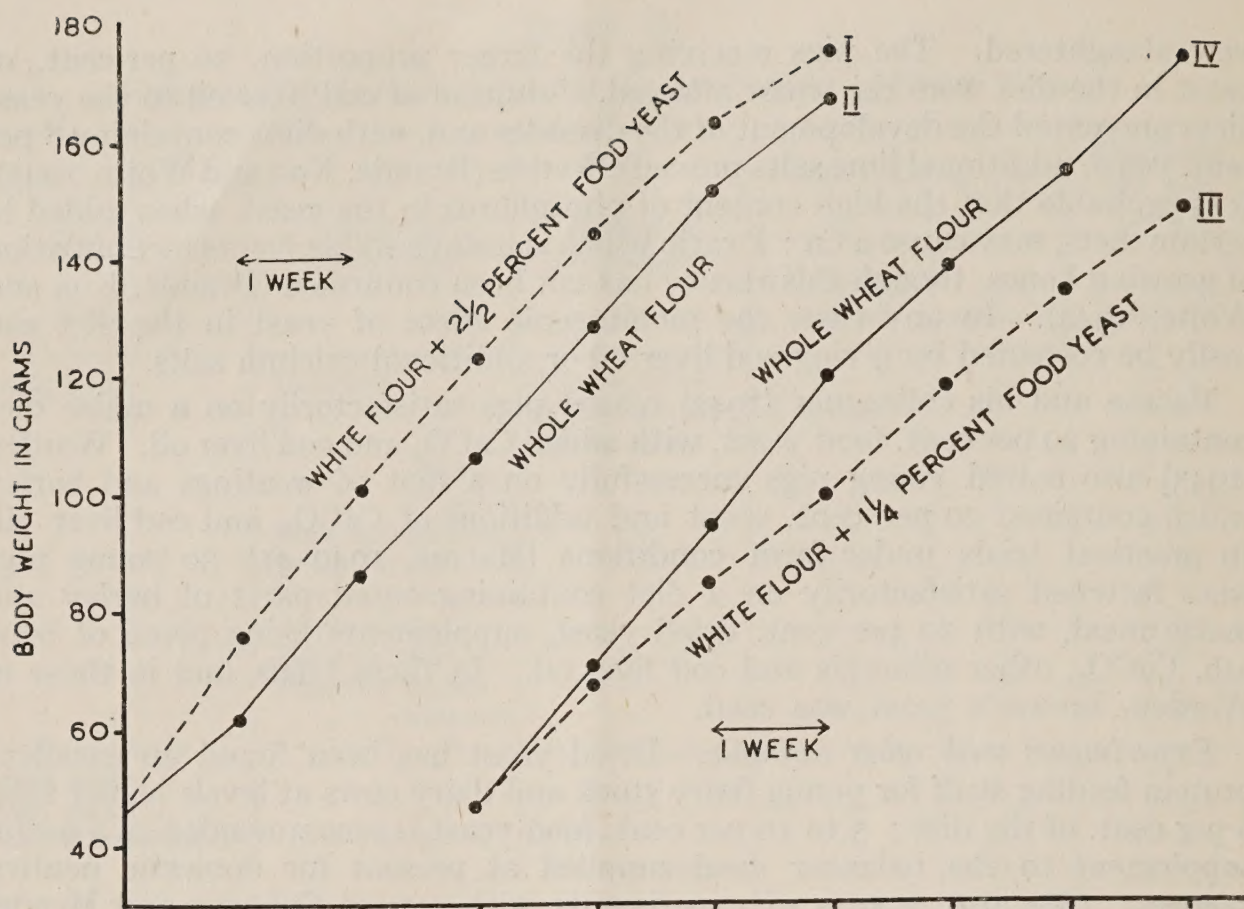


FIG. 1

Growth curves of newly weaned rats receiving diets in which B vitamins were provided, respectively, as food yeast (*Torula utilis*) added to a white flour (73 per cent. extraction of the grain) diet, and as those naturally present in whole wheat flour (100 per cent. extraction). Both flours were specially milled from the same grist by the Research Association of British Flour Millers. Extra protein as casein was added to each diet, to bring the content up to 18 per cent., the optimal amount for growth. The rats receiving diets I and II, and those receiving diets III and IV, were litter mates; each curve represents average growth rate of 5 to 6 rats.

Curve I Diet contained B vitamins from white flour + $2\frac{1}{2}$ per cent. yeast.

Curve II " " " " " whole wheat flour.

Curve III " " " " " white flour + $1\frac{1}{4}$ per cent. yeast.

Curve IV " " " " " whole wheat flour.

(c) *Food Yeast as a Supplement to a "Poor European" Human Diet.*—In a series of trials with rats, made at the Nutrition Laboratory, Coonoor (Aykroyd, 1942), the effect was studied of adding dried food yeast to a diet of mixed foodstuffs modelled upon the poor European wartime basic dietary drawn up for the Committee on Scientific Food Policy. Certain modifications were introduced to suit Indian conditions. The composition of this diet was as follows :—

Basic Diet

	oz.		oz.
White bread ..	13.7	Carrots ..	1.0
White flour ..	1.1	Turnips ..	0.5
Barley ..	0.7	Tomatoes ..	0.5
Rice ..	0.3	Lentils ..	0.5
Cornflour ..	0.1	Peanuts ..	0.5
Potatoes ..	8.0	Onions ..	0.5
Margarine ..	0.4	Garlic ..	0.5
Cabbage ..	2.0	White sugar ..	2.3
Lettuce ..	1.0		

The following foods, which were included in the original diet, *viz.*, milk 10 oz., meat 3.4 oz., fish 1.1 oz. and cheese 0.5 oz., were omitted, as it was assumed that the value of the food yeast would be mainly as a substitute for

these foods. For purposes of comparison, however, additional tests were made in which these were added separately to the basic diet (I) as dried whole milk equivalent to 10 oz. liquid milk, or (2) as 3.4 oz. meat and 1.1 oz. fish, or (3) as 0.5 g. dried *Torula utilis*. The yeast was grown in the Coonoor Laboratories upon a molasses medium, from a strain of *Torula utilis* obtained from the Chemical Research Laboratories at Teddington. Moreover, as the basic diet might be expected to be low in calcium, a fourth series (4) was included in which CaCO_3 was given in the proportion of 65 mg. to each 100 g. white flour contained in the diet, this amount being in accordance with the recommendation of the Medical Research Council (1941) for the addition of lime salts to flour for bread making.

The growth curves set out in Figure 2 show that with each addition to the basic diet the rate of weight increase was improved, but that the effect of the yeast exceeded that of milk or of fish. The warning is, however, mentioned that these experiments should be interpreted as showing the value of food yeast for provision of B vitamins and protein, but not of vitamin A. The young rats when receiving the experimental diets were well stored with vitamin A. The stock diet was rich in this vitamin, and the ill effect of any limitation of vitamin A in the experimental diets would therefore not be apparent within 10 to 12 weeks, which was the period of the experiments. If the tests had been continued for a longer time the superiority of the milk addition might have become evident.

The results of the above experiments with animals show that the addition of food yeast greatly improves the nutritive value of a diet whose protein is otherwise derived mainly from cereals, the biological value of the mixture of the cereal proteins with those of yeast being equal to that of a similar mixture with those of milk. The good effects of the addition of food yeast to a white flour diet have demonstrated its value as a source of B vitamins.

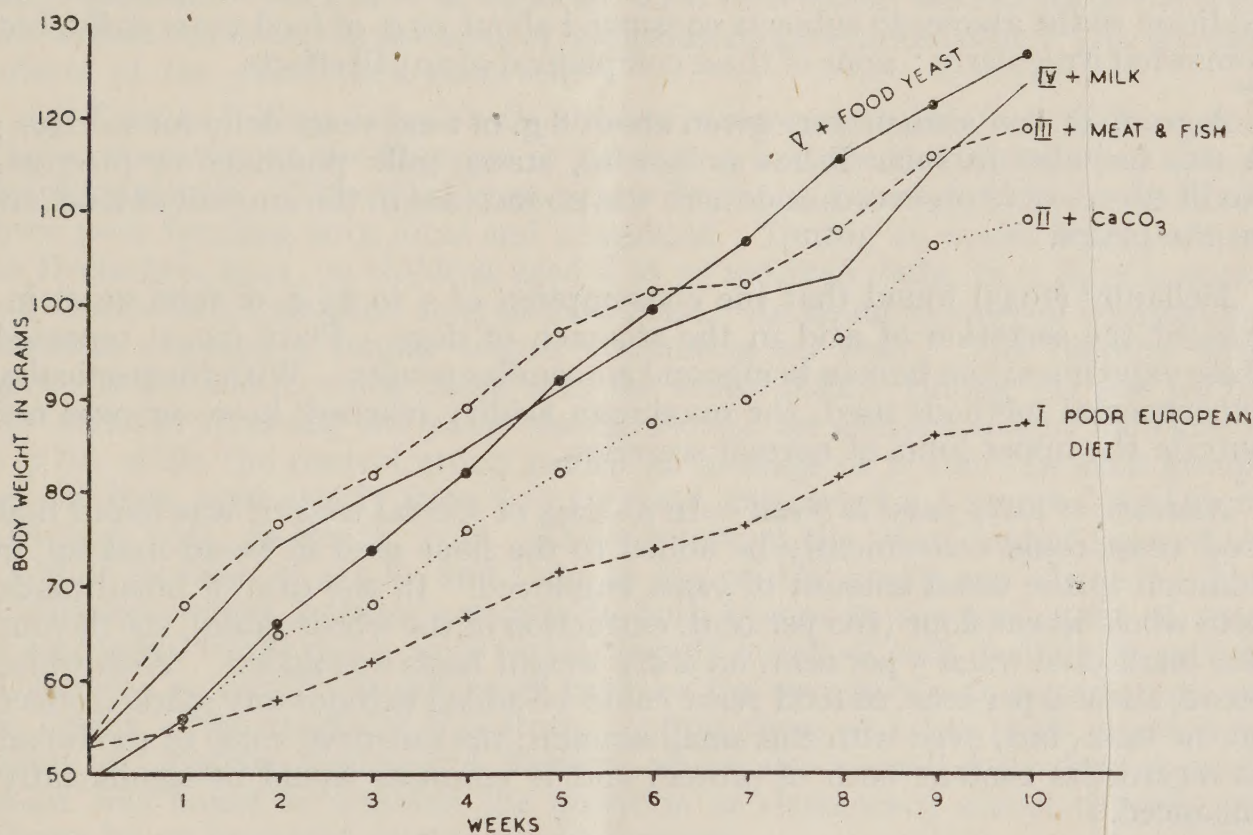


FIG. 2

Growth curves of young rats receiving a "poor European wartime diet" (Curve I) with various supplements:—

Curve II + calcium carbonate; Curve III + meat and fish; Curve IV + milk; Curve V + food yeast (*Torula utilis*).

(3) Nutritional Trials on Human Subjects

The two probable objects of adding food yeast to a human diet would be improvement of its protein and of its content of B vitamins. The trials reported below show that at least $\frac{1}{4}$ oz. can be taken daily without risk of digestive disturbance. This amount, which would increase the *amount* of dietary protein by only about 3 g. daily, may seem to be negligible; it may nevertheless disproportionately improve its *quality*, owing to the supplementing action of the assortment of amino-acids in yeast proteins for the proteins of cereals, of which most "poor" diets are largely composed. A mixture of yeast protein and cereal proteins affords a better assortment of amino-acids for the growing animal than either alone. While this effect cannot be neglected, it may not in general be as important as that of the B vitamins introduced with these relatively small doses of food yeast. At present we do not know whether larger amounts of food yeast could be satisfactorily included in the diet as a source of protein for badly undernourished people.

OBSERVATIONS ON ADULTS IN BRITAIN

To test human tolerance for food yeast, Macrae (1941-42) organised a series of trials among 85 subjects living in Cambridge, of ages varying from 7 months to 75 years. Of these, 14 children under 5 years of age took up to 5 g., and the baby of 7 months 2 g., of food yeast, without any observed digestive or other disturbance. Of the adults, 33 consumed 15 g. daily for periods of 2 to 7 weeks, either mixed with flour and baked in bread or added to soups, porridge or potatoes. Only three complained of digestive upsets; of these, one was an allergic subject and the other two reported vague digestive disturbance but gave no details. One subject consumed 64 g. daily for 4 days without ill effect. In addition to the above, 37 subjects consumed about 10 g. of food yeast daily, but somewhat irregularly; none of these complained of any ill effects.

A group of 100 airmen were given about 8 g. of food yeast daily for 10 days; it was included in such dishes as rissoles, stews, milk puddings or piecrust. No ill effects were observed, and there was no increase in the amount of food left on the plates.

Mellanby (1943) found that the consumption of 5 to 15 g. of food yeast increased the secretion of acid in the stomach of dogs. Platt (1943) repeated these experiments on human beings and got similar results. With the particular experimental methods used, the maximum acidity reached, however, was not outside the upper limit of normal secretion.

Addition of extra yeast to bread.—In a series of special trials it was found that food yeast could conveniently be added to the flour used in bread making, in addition to the usual amount of yeast employed. In the case of bread made with whole wheat flour (100 per cent. extraction of the wheat grain), the flavour was unaffected when 5 per cent. on a dry weight basis was added. With white bread, about 2 per cent. of food yeast could be added without any marked effect on the taste, but, even with this small amount, the nutritive value of the bread as regards its content both of protein and B vitamins would be significantly enhanced.

Light and Frey (1943) showed that addition of extra yeast to white bread supplied not only riboflavin in which the latter is poor, but in addition the amino-acids valine and lysine in which it also is deficient. The improvement in growth of young rats when 5 per cent. dry yeast was added to a white flour diet was equal to that given by 6 per cent. dried skim milk.

OBSERVATIONS ON CHILDREN

(1) *Trials at Ponteland School, Newcastle, and at a Boys' Camp School*, arranged by Dr. H. E. Magee.—Of a group of 160 children who received about $\frac{1}{4}$ oz. (8 g.) dried food yeast daily with breakfast porridge, 20 reported digestive and other upsets, as compared with 7 in the control group of 140, who received no yeast. When the daily dose was divided into $\frac{1}{8}$ oz. at breakfast and $\frac{1}{8}$ oz. at dinner, there was no difference in the incidence of digestive disturbances between the children receiving yeast and the control group.

(2) *Trial at the Poplars Children's Home, Oxford*, arranged by Professor Peters, with the assistance of Mr. and Mrs. Worsley (Wardens).—Forty children, aged from 8 to 15 years, were given daily $\frac{1}{4}$ oz. dried food yeast with their breakfast porridge, controls being provided by 20 children who received the same diet without addition of yeast. During the trial, which lasted a month, there were 6 cases of diarrhoea, in some instances with vomiting, in the group receiving yeast; all these disturbances, however, occurred during two short periods. It was concluded that children can tolerate $\frac{1}{4}$ oz. of food yeast daily, given at one meal, but that temporary digestive disturbances may occur.

(3) *Trial at the Oxford City Children's Home*, arranged by the Oxford Nutrition Survey (Dr. H. M. Sinclair) with the co-operation of the Matron, Mrs. Morgan.—In this Home, one of two groups of 18 (later reduced to 12) similar boys aged 7 to 12 years received $\frac{1}{4}$ oz. (7 g.) of food yeast with their porridge daily for nearly 3 years. Regular examinations were made of the weight and height of the boys in both groups, of their eyes (slit lamp examination) and gums, and of the protein and haemoglobin content of the blood; saturation tests were made of riboflavin and vitamin B₁, and functional trials made of dynamometer pull, bar hanging and of visual and auditory acuity. The diet of the Home, apart from the yeast addition, was satisfactory and contained from $\frac{1}{2}$ to 1 pint of milk daily per head. As was to be expected with such a diet, the results of the tests showed no advantage in the boys of one group relative to the other. No adverse effects of the yeast were observed.

(4) *Trial at Village School in Oxfordshire*, arranged by Dr. D. C. Wilson with the co-operation of the Director of Education and the County Medical Officer for Oxfordshire.—This rural elementary day school contained many children from poor families, both local and evacuated. During 10 weeks from October to December, 1941, 79 children aged 6 to 10 received daily, on 5 days a week, a biscuit which contained 10 g. of food yeast. An equal number of comparable children received a similar biscuit containing no yeast. The biscuits were given at the mid-morning break with the school milk. During the test period the children receiving the yeast biscuit showed an average weight increase of 1.7 lb., while the control group gained an average of 1.2 lb. In each group, 40 children, aged mostly from 8 to 10 years, completed a 5 months' trial from October, 1941, to March, 1942. Those receiving the yeast biscuit showed an average increase of 4.4 lb. and those in the control group one of 3.1 lb. The additional weight increase common to both groups in the early part of 1942 is attributed to the much more regular supply of school milk during this period. There was no significant difference between the two groups as regards increase in height. The results of this study confirm those of other trials, previously made at Chipping Norton and Burford, where also a small daily dose of dried yeast was found to improve the nutrition of elementary school children, as shown by an increased rate of weight increase.

(5) *Trials on Children Evacuated from Gibraltar*, arranged by Dr. J. D. King.—These trials were made on 41 children aged 10 to 14 years, suffering from gingival disease, the lesions of which strongly resembled the pre-ulcerative or slight ulcerative stages of so-called Vincent's disease. Of 24 affected

children who received $3\frac{1}{2}$ g. of food yeast daily for 8 weeks, 17 showed complete recovery, four were much improved, and in three the condition remained unchanged; in these cases there was a heavy deposition of tartar about the necks of the teeth, which probably retarded recovery. Of 17 slightly affected children, who served as controls and received no yeast, three showed spontaneous recovery, five slight improvement and nine an unchanged or deteriorated condition. Nicotinic acid, 50 mg. daily, given without or with local treatment, was also found effective (King, 1944).

TRIALS IN COLONIAL TERRITORIES

Trials organised by Dr. B. S. Platt are being carried out with food yeast in places where there is clinical evidence of a shortage in the diet of B₂ vitamins and possibly of protein.

(A) *Trinidad*.—Dr. E. Muir, at the leper settlement at Chacachacare, has noted that the signs of leprosy in the skin, eyes and tongue resemble some of the symptoms of nutritional deficiency, and he points out that it is therefore difficult to assess the value of giving food yeast by clinical evidence. He has, however, made the important observation that a group of patients receiving a supplement of food yeast developed an improved appetite—so much so, indeed, that there were complaints of hunger on rations which had hitherto been found adequate.

TABLE III

Trials of Food Yeast in Nigeria

(a) *Effect of giving 7 g. food yeast daily for 7 weeks to 145 Nigerian male lunatics and an inert powder to a control group of 68 female lunatics.*

	Test group (males)		Control group (females)	
	at beginning	at end	at beginning	at end
Total number	145	140	68	65
Cases of deficiency of B ₂ vitamins				
Severe	22	2	5	11
Mild	23	16	20	14
Total	45	18	25	25

(b) *Effect of giving 4 g. food yeast daily for 5 weeks to Nigerian prisoners showing signs of severe deficiency of B₂ vitamins.*

	Test group			Control group	
	at beginning	at end	after 3 weeks without treatment	at beginning	at end
Cases showing deficiency symptoms	18	5	11	12	9*
Severe	18	1	5		
Mild	0	4	6		

* See text, p. 15.

(B) *Nigeria*.—Dr. W. Hughes is making trials of food yeast in certain institutions where there is evidence of deficiency of B₂ vitamins. He has not yet completed his observations but has reported the following promising results.

(i) In a lunatic asylum, the number of male patients (45 out of a total of 145) showing signs of deficiency of B₂ vitamins was reduced to less than one-half, and the severity of the symptoms diminished, after 7 g. of food yeast had been taken daily for 7 weeks. In a control group of female lunatics, who received an inert powder, there was no diminution in the number showing signs of deficiency, and an increase occurred in the severity of the symptoms (see Table III (a)).

(ii) A group of 18 prisoners showing signs of severe deficiency of B₂ vitamins received 4 g. of food yeast daily for 5 weeks, after which the number showing symptoms was reduced to five, of whom only one remained severely affected; during the subsequent 3 weeks, in which no food yeast was given, several relapses occurred. In a control group of 12 untreated prisoners, two mild cases showed disappearance of symptoms and one severe case which had deteriorated was cured by a few days' treatment with riboflavin (see Table III (b)).

Some promising observations have been recorded also in East Africa, where, however, it has not yet been possible to arrange trials under close control.

SUMMARY

1. Food yeast contains proteins, in amount equal to about half its dry weight, which, when included in a diet of which the protein is otherwise derived mainly from cereals, possess a high nutritive value, approaching that possessed by milk proteins.

2. Like other types of yeast, food yeast is one of the richest known sources of B vitamins, including vitamin B₁, riboflavin and nicotinic acid; in this respect it is rivalled only by liver, the values being calculated on a dry weight basis.

3. Dried food yeast has been found to be an acceptable and generally palatable food for human subjects, both children and adults. Taken in small amounts, $\frac{1}{8}$ to $\frac{1}{2}$ oz. (3 to 14 g.) daily, it provides a valuable addition to the B vitamins contained in an ordinary diet. In one trial with children, consumption of 8 g. of dried food yeast daily in a biscuit distributed on 5 days weekly was associated with an improved rate of increase in weight. A daily dose of $3\frac{1}{2}$ g. was given with benefit to a group of children suffering from gingivitis.

4. About $\frac{1}{2}$ oz. of dried food yeast may be regarded as a maximum adult daily dose in ordinary circumstances; $\frac{1}{4}$ oz. daily may be taken without any risk of digestive disturbance.

5. In Nigeria, subjects with symptoms of deficiency of B₂ vitamins have shown striking improvement, or cures, after 5 to 7 weeks' treatment with 4 to 7 g. of food yeast daily.

REFERENCES

- AYKROYD, W. R. (1942). Unpublished work.
- BACHARACH, A. L. (1941). *Nutr. Abst. Rev.*, **10**, 459.
- BOOTH, R. G. and BARTON-WRIGHT, E. C. (1944). *Lancet, Lond.*, **i**, 565.
- BRAUDE, R., KON, S. K. and WHITE, E. G. (1943). *J. comp. Path.*, **53**, 161.
- BRAUDE, R., KON, S. K. and WHITE, E. G. (1944). *J. comp. Path.*, **54**, 88.
- BÜNGER, H. (1939). *Biederm. Zbl. (B), Tierernährung*, **11**, 157.
- CHICK, H. (1941). Unpublished work.
- CHICK, H. and SLACK, E. B. (1945). *Biochem. J.*, **39**, 164.
- COLONIAL FOOD YEAST, LTD. (1944). *Food Yeast: A Venture in Practical Nutrition*. London: Waterlow and Sons.
- COPPING, A. M. (1943 (a)). *Biochem. J.*, **37**, 12.
- COPPING, A. M. (1943 (b)). Unpublished work.
- ECONOMIC ADVISORY COUNCIL. COMMITTEE ON NUTRITION IN THE COLONIAL EMPIRE. (1939). *First Report*, part 1, paras. 185-187. London: H.M.S.O.
- EL SADR, M. M., MACRAE, T. F. and WORK, C. E. (1940). *Biochem. J.*, **34**, 601.
- FIXSEN, M. A. B. and ROSCOE, M. H. (1937-38). *Nutr. Abst. Rev.*, **7**, 823.
- HARRIS, L. J. and WANG, Y. L. (1942). *Chem. and Indust.*, **61**, 27.
- HIMSWORTH, H. P. and GLYNN, L. E. (1944). *Clin. Sci.*, **5**, 93; 133.
- KING, J. D. (1944). *Lancet, Lond.*, **ii**, 495.
- KLOSE, A. A. and TEVOLD, M. L. (1944). *Proc. Soc. exp. Biol. Med.*, **56**, 98.
- KON, S. K. and MARKUSE, Z. (1931). *Biochem. J.*, **25**, 1476.
- LEAGUE OF NATIONS. TECHNICAL COMMISSION ON NUTRITION. (1938). *Bull. Health Organis. L.o.N.*, **7**, 666.
- LIGHT, R. F. and FREY, C. N. (1943). *Cereal Chem.*, **20**, 645.
- MACRAE, T. F. (1940-41). Unpublished work.
- MACRAE, T. F. (1941-42). Unpublished work.
- MACRAE, T. F., BARTON-WRIGHT, E. C. and COPPING, A. M. (1944). *Biochem. J.*, **38**, 132.
- MACRAE, T. F., EL SADR, M. M. and SELLERS, K. C. (1942). *Biochem. J.*, **36**, 4604.
- MEDICAL RESEARCH COUNCIL. (1941). *Lancet*, **ii**, 703.
- MEDICAL RESEARCH COUNCIL. (1945). *Nutritive Values of Wartime Foods*. M.R.C. War Memorandum No. 14. London: H.M.S.O.
- MELLANBY, E. (1943). Unpublished work.
- MITCHELL, H. H. (1924). *J. biol. Chem.*, **58**, 905.
- OSBORNE, T. B. and MENDEL, L. B. (1919). *J. biol. Chem.*, **38**, 223.
- PLATT, B. S. (1943). Unpublished work.
- PLATT, B. S. and GLOCK, G. E. (1943). *Biochem. J.*, **37**, 439.
- PLIMMER, R. H. A., ROSEDALE, J. L., RAYMOND, W. H. and LOWNDES, J. (1934). *Biochem. J.*, **28**, 1863.
- STILL, E. V. and KOCH, F. C. (1928). *Amer. J. Physiol.*, **87**, 225.
- WAISMAN, H. A. and ELVEHJEM, C. A. (1941). *The Vitamin Content of Meat*. Minneapolis: Burgess Publishing Co.
- WORDEN, A. N. (1943). *J. comp. Path.*, **53**, 190.

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